Particulate Matter

PM_{10} Air Quality Concentrations		
1980–99		NA
1990–99	18%	decrease
1998–99	1%	increase

PM_{10} Emissions		
1980–99		NA
1990–99	15%	decrease
1998–99	9%	decrease

$PM_{2.5}$ Air Quality Concentrations	
1980–99	Trend not yet available
1990–99	Trend not yet available
1998–99	Trend not yet available

$PM_{2.5}$ Emissions		
1980–99		NA
1990–99	17%	decrease
1998–99	18%	decrease

Worth Noting:

PM_{10}

- Between 1998 and 1999, annual average PM_{10} concentrations increased nationally for the first time since EPA began tracking PM_{10} trends in 1988. The small increase (1 percent) is largely influenced by increases in the West, particularly in California. PM_{10} concentrations in California were higher than normal from September to December 1999, a period which coincided with major wildfires and particularly dry conditions.
- Beginning in 1998, the number of monitoring sites in the PM_{10} network began to decrease. This follows the PM monitoring strategy published in July 1997 which encourages reducing the number of PM_{10} monitoring sites in areas of low concentrations where the PM_{10} NAAQS are not expected to be violated. In 1999, only 667 sites had data, compared to 887 sites in 1998 and 992 sites in 1997.
- The Franklin Smelter facility, responsible for historically high recorded PM_{10} concentrations in Philadelphia, shut down in August 1997 and dismantled in late 1999. This has brought peak concentrations down below the level of the standard at the nearby monitoring site. In 1998 and 1999, the second maximum was only 61 and 52 µg/m^3, respectively, compared to 264 µg/m^3 in 1997.

$PM_{2.5}$

- The first complete year of $PM_{2.5}$ data (1999) collected by EPA's Federal Reference Method Monitoring network confirms that $PM_{2.5}$ varies regionally. In the East, higher levels extend from the Southeastern to Mid-Atlantic states and west into the Ohio River Valley area. Florida and the Northeast (New York State to Maine) tend to have annual mean concentrations below 15 µg/m^3. California, especially central to southern California, seems to be the only area widespread in the West with annual mean concentrations above 15 µg/m^3.
- Data from the IMPROVE network show that average $PM_{2.5}$ concentrations in the rural east decreased 7 percent from 1998–1999.
- Sulfate concentrations in the rural east decreased 7 percent based on the 10 IMPROVE sites (and 10 percent based on the 34 CASTNet sites) from 1998–1999.
- Organic carbon concentrations in the rural east decreased 4 percent from 1998–1999, and are still up 18 percent from 1997.

Nature and Sources

Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air. PM originates from a variety of sources, including diesel trucks, power plants, wood stoves and industrial processes. The chemical composition and physical properties of these particles vary widely. While individual particles cannot be seen with the naked eye, collectively they can appear as black soot, dust clouds, or haze.

Particles less than or equal to 2.5 micrometers in diameter, or $PM_{2.5}$, are known as "fine" particles. Those larger than 2.5 micrometers but less than or equal to 10 micrometers are known as "coarse" particles. PM_{10} refers to all particles less than or equal to 10 micrometers in diameter.

Fine particles result from fuel combustion (from motor vehicles, power generation, industrial processes), residential fireplaces and wood stoves. Fine particles also can be formed in the atmosphere from gases such as sulfur dioxide, nitrogen oxides, and volatile organic compounds.

Coarse particles are generally emitted from sources such as vehicles traveling on unpaved roads, materials handling, and crushing and grinding operations, and windblown dust. Fine and coarse particles typically exhibit different behavior in the atmosphere. Coarse particles can settle rapidly from the atmosphere within hours, and their spatial impact is

Note: The methods used to estimate PM_{10} emissions of some source categories are not consistent in all years over the period between 1980 and 1999. Changes from one method to another make the emissions trend over time appear different than it actually has been. Of particular note is that for 1999 PM_{10} emissions from three source categories of open burning are estimated differently than in previous years and show a substantial increase compared to estimates for prior years. These categories of open burning of residential waste, yard waste, and land clearing waste are included in the "industrial processing" sector of Figures 2-39 and 2-40. The apparent increase in emissions from this sector, and in total PM_{10} emissions, from 1998–1999 is the result of this change in estimation methodology.

typically limited because they tend to fall out of the air in the downwind area near their emission point. Larger coarse particles are not readily transported across urban or broader areas, because they are generally too large to follow air streams and they tend to be removed easily by impaction on surfaces. Smaller-sized coarse particles can have longer lives and longer travel distances, especially in extreme circumstances, such as dust storms.

Because fine particles remain suspended for longer times, typically on the order of days to weeks and travel much father than coarse particles, all else being equal, fine particles are theoretically likely to be more uniformly dispersed at urban and regional scales than coarse particles. Analyses of 1999 $PM_{2.5}$ data from sites in Atlanta, Detroit, Phoenix, and Seattle indicate that $PM_{2.5}$ concentrations tend to be highly correlated among sites within an urban area. In contrast, coarse particles tend to exhibit more localized elevated concentrations near sources.[28]

Health and Environmental Effects

Scientific studies show a link between inhalable PM (alone, or combined with other pollutants in the air) and a series of significant health effects. Inhalable PM includes both fine and coarse particles. Both coarse and fine particles can accumulate in the respiratory system and are associated with numerous adverse health effects. Exposure to coarse particles is primarily associated with the aggravation of respiratory conditions such as asthma. Fine particles are most closely associated with adverse health effects including decreased lung function, increased hospital admissions and emergency room visits, increased respiratory symptoms and disease, and premature death. Sensitive groups that appear to be at greatest risk to such PM effects include the elderly, individuals with cardiopulmonary disease such as asthma or congestive heart disease, and children.

Particulate matter also can also cause adverse impacts to the environment. Fine particles are the major cause of reduced visibility in parts of the United States, including many of our national parks. Other environmental impacts occur when particles deposit onto soils, plants, water, or materials. For example, particles containing nitrogen and sulfur that deposit onto land or water bodies may change the nutrient balance and acidity of those environments so that species composition and buffering capacity change. Particles that are deposited directly onto the leaves of plants can, depending on their chemical composition, corrode leaf surfaces or interfere with plant metabolism. Finally, PM causes soiling and erosion damage to materials, including culturally important objects such as carved monuments and statues.

Primary and Secondary PM Standards

The standards for PM_{10} include both short- and long-term NAAQS. The short-term (24-hour) standard of 150 $\mu g/m^3$ is not to be exceeded more than once per year on average over three years. The long-term standard specifies an expected annual arithmetic mean not to exceed 50 $\mu g/m^3$ averaged over three years.

The standards for $PM_{2.5}$ are set at 15 $\mu g/m^3$ and 65 $\mu g/m^3$, respectively, for the annual and 24-hour standards.[29] These are the primary, or health-based, standards. The secondary, or welfare-based, standards for PM_{10} are identical to the primary standards. The secondary (welfare-based) $PM_{2.5}$ standards were made identical to the primary standards.

Numerous industry and environmental petitioners, including the American Trucking Associations (ATA), challenged the O_3 and PM standards in the United States Court of Appeals for the District of Columbia Circuit. On May 14, 1999, a three-judge panel of that court concluded that EPA's interpretation of the Clean Air Act unconstitutionally delegated legislative power to EPA and remanded the standards to EPA. EPA appealed that ruling, and on February 27, 2001, the Supreme Court unanimously upheld the constitutionality of Clean Air Act section 109 and affirmed EPA's ability to set NAAQS based solely on public health and welfare factors, without consideration of costs, which are considered in the implementation of the standards. The court rejected the D.C. Circuit's conclusion that EPA's interpretation of the implementation provisions violated the statute's clear terms, but nevertheless remanded the implementation policy to EPA on the basis that EPA's policy was not a reasonable interpretation of ambiguous statutory language. Because the D.C. Circuit originally remanded, but did not vacate the O_3 and $PM_{2.5}$ standards, they have remained legally effective throughout the ongoing litigation. The case has now been returned to the Court of Appeals, where the remaining issues are to be considered in accordance with the decision of the Supreme Court.

For a variety of reasons, EPA has not yet taken actions to implement either standard. The litigation over the PM NAAQS has not yet affected EPA or state activities related to these standards. EPA cannot start implementing the 1997 $PM_{2.5}$ standards until EPA and the states have collected three years of monitoring data to determine which areas are not attaining the standards. The fine particle monitoring network has been operational since 1999 and was completed in 2000. In most cases, areas would not be designated "attainment" or "nonattainment" for the $PM_{2.5}$ standards until 2004–2005. Refer to **http://www.epa.gov/airlinks** for up-to-date information concerning actions surrounding the revised standards.

National 10-Year PM_{10} Air Quality Trends

Since 1988 represents the first complete year of PM_{10} data for most monitored locations, a 20-year trend is not available. However, the most recent 10-year period (1990–1999) shows that the national average of annual mean PM_{10} concentrations at 954 monitoring sites decreased 18 percent in Figure 2-37. The downward trend is apparent through 1998. However, between 1998 and 1999, the national average increased 1 percent. This slight increase is largely influenced by increases in the West, particularly in California. PM_{10} concentrations in California were higher than normal from September–December 1999, a period which coincided with major wildfires and particularly dry conditions.

When the sites are grouped as rural, suburban, and urban, as in Figure 2-38, the trend is similar to the national trend. The highest values are generally found at the urban sites, followed closely by the suburban sites. The annual mean is much

Figure 2-37. Trend in annual mean PM_{10} concentrations, 1990–1999.

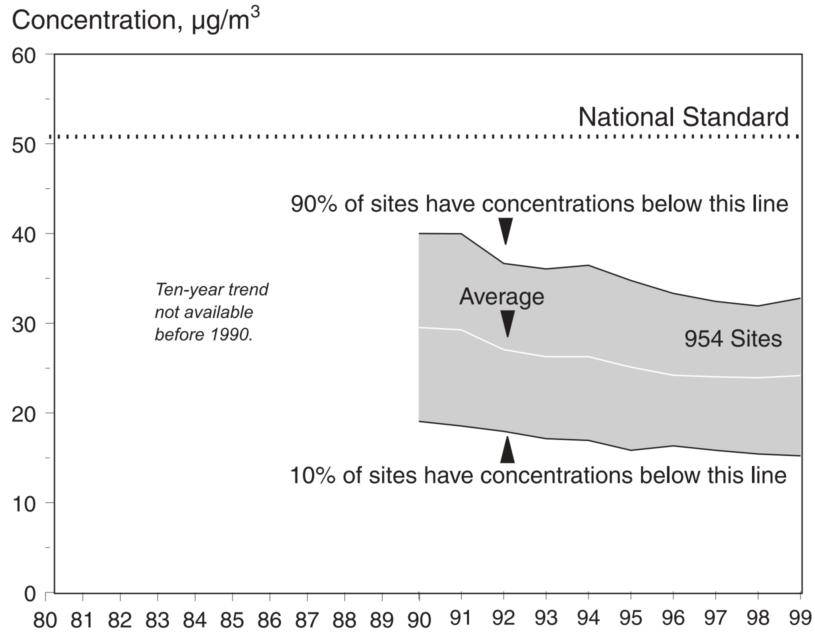


Figure 2-38. PM_{10} annual mean concentration trends by location, 1990–1999.

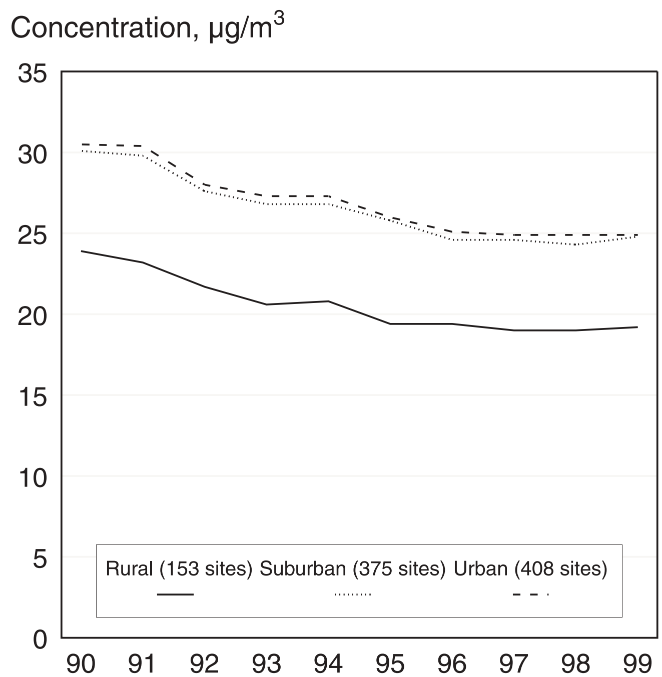
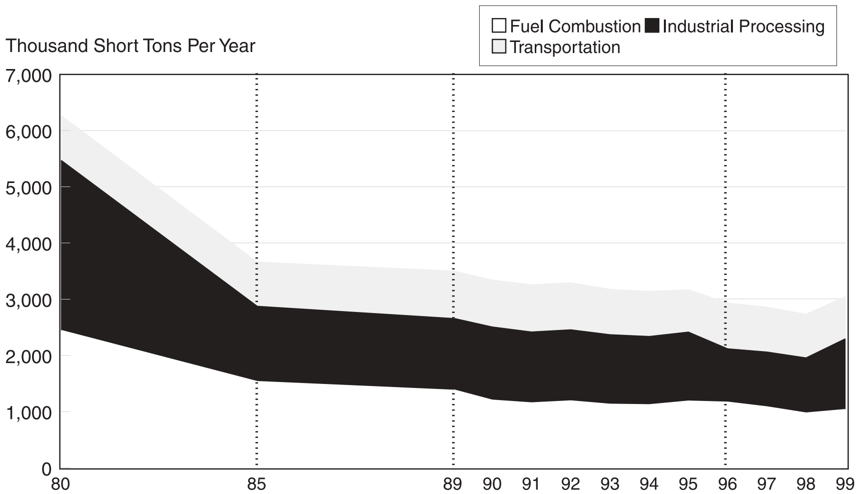


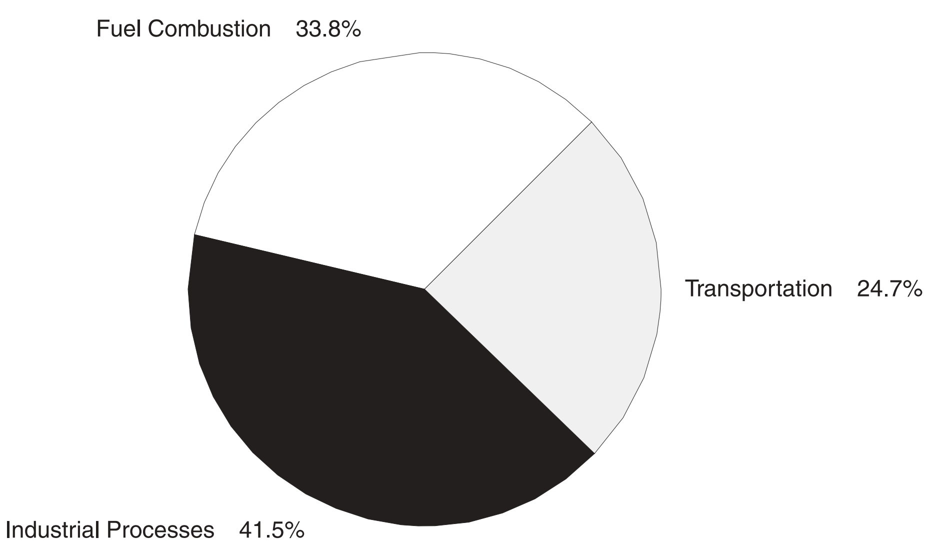
Figure 2-39. National PM_{10} emissions trend, 1980–1999 (traditionally inventoried sources only).



Notes: Emissions data not available for consecutive years 1980–1989.

Emission estimation methods continue to evolve and improve over time. Methods have changed for many significant categories beginning with the years 1985, 1990, and 1996 and consequently are not consistent across all years in this trend period. See Appendix B Emissions Estimates Methodology for additional information.

Figure 2-40. PM_{10} emissions from traditionally inventoried source categories, 1999.



lower at the rural sites, which are generally located away from local sources of PM_{10}.

Beginning in 1998, the number of monitoring sites in the PM_{10} network began to decrease. This follows the PM monitoring strategy published in July 1997 which encourages reducing the number of PM_{10} monitoring sites in areas of low concentrations where the PM_{10} NAAQS are not expected to be violated. Specifically, it calls for eliminating sites not needed for trends or with maximum concentrations less than 60 percent of the NAAQS.[30] In 1999, only 667 sites had data, compared to 887 sites in 1998 and 992 sites in 1997. This decrease in the number of monitors has not affected the calculation of the national trend.

Several factors have played a role in reducing PM_{10} concentrations. Where appropriate, states required emissions from industrial sources and construction activities to be reduced to meet the PM_{10} standards. Measures were also adopted to reduce street dust emissions, including the use of clean anti-skid materials like washed sand, better control of the amount of material used, and removal of the material from the street as soon as the ice and snow melt. Cleaner burning fuels like natural gas and fuel oil have replaced wood and coal as fuels for residential heating, industrial furnaces, and electric utility and industrial boilers.

National PM_{10} Emissions Trends

Nationally, annual estimates of PM_{10} direct emissions decreased 15 percent between 1990 and 1999 (see Table A-6). Direct PM_{10} emissions are generally examined in two separate groups. First there are the emissions from the more traditionally inventoried sources, shown in Figures 2-39 and 2-40. These include fuel combustion, industrial processes, and transportation. Of these, the fuel combustion category saw the largest decrease over the 10-year period (14 percent), with most of the decline attributable to a decrease in emissions from electric utility coal and oil combustion. Emissions from the industrial processes category decreased 3 percent, and emissions from the transportation category decreased 10 percent. The recent upward movement between 1998 and 1999 for industrial processing is attributed to new sources of emissions for open burning (of residential yard wastes and land clearing debris) that had not been characterized previously.

The second group of direct PM_{10} emissions is a combination of miscellaneous and natural sources including agriculture and forestry, wildfires and managed burning, and fugitive dust from paved and unpaved roads. It should be noted that fugitive dust emissions from geogenic wind erosion have been removed from the emissions inventory for all years, since the annual emission estimates based on past methods for this category are not believed to be representative. As Figure 2-41 shows, these miscellaneous and natural sources actually account for a large percentage of the total direct PM_{10} emissions nationwide, although they can be difficult to quantify compared to the traditionally inventoried sources. The trend of emissions in the miscellaneous/natural group may be more uncertain from one year to the next or over several years because these emissions tend to fluctuate a great deal from year to year. It should be noted that a change in methodology occurred between 1995 and 1996 in calculating PM_{10} emissions from unpaved roads. This has led to lower PM_{10} emissions from 1996 through 1999 than would have been predicted using the older methodology.

Figure 2-41. Total PM_{10} emissions by source category, 1999.

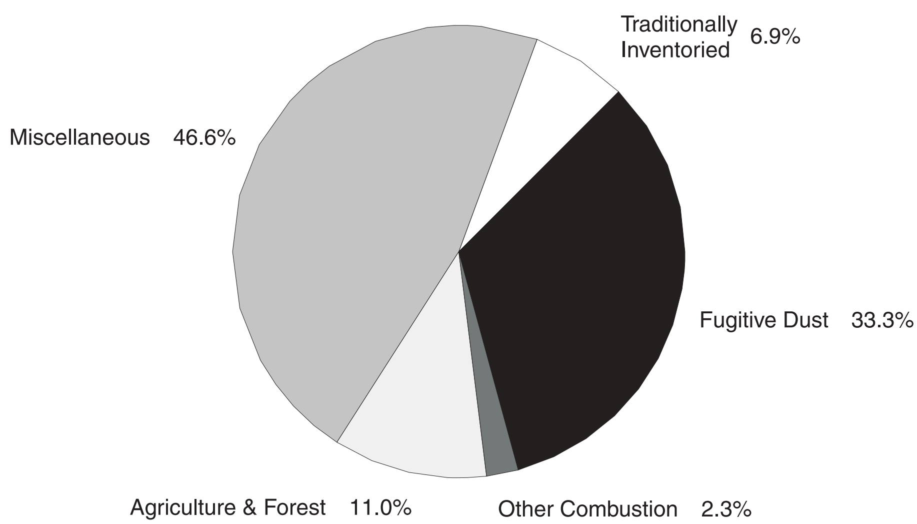


Table A-6 lists PM_{10} emissions estimates for the traditionally inventoried sources for 1990–1999. Miscellaneous and natural source PM_{10} emissions estimates are provided in Table A-7.

Figure 2-42 shows the emission density for PM_{10} in each U.S. county. PM_{10} emission density is the highest in the eastern half of the United States, in large metropolitan areas, areas with a high concentration of agriculture such as the San Joaquin Valley in California and along the Pacific coast. This closely follows patterns in population density. One exception is that open biomass burning is an important source category that is more prevalent in forested areas and in some agricultural areas. Fugitive dust is an important component in arid and agricultural areas.

PM_{10} Regional Air Quality Trends

Figure 2-43 is a map of regional trends for the PM_{10} annual mean from 1990–1999. All 10 EPA regions show decreasing trends over the 10-year period, with declines ranging from 5–33 percent. The largest decreases are generally seen in the western part of the United States. This is significant since PM_{10} concentrations are typically higher in the West. In the western states, programs such as those with residential wood stoves and agricultural practices have helped reduce emissions of PM_{10}. In the eastern United States, the Clean Air Act's Acid Rain Program has contributed to the decrease in PM_{10} emissions. The program has reduced

Figure 2-42. PM_{10} emissions density by county, 1999.

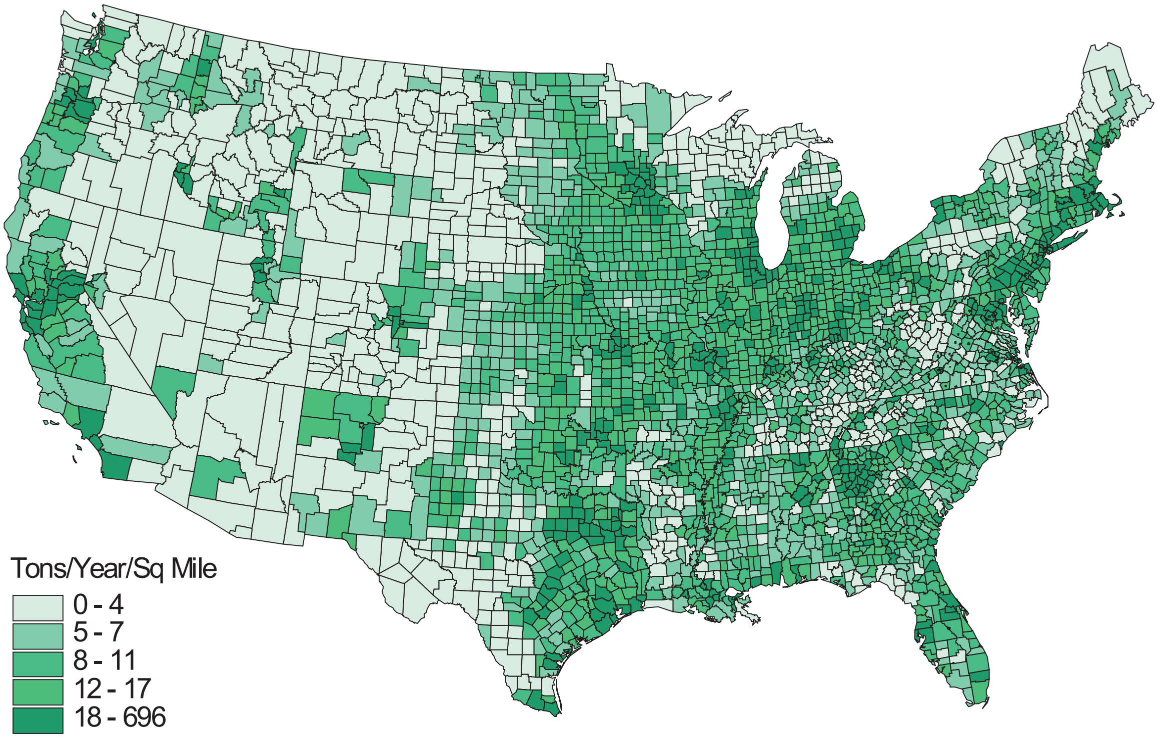
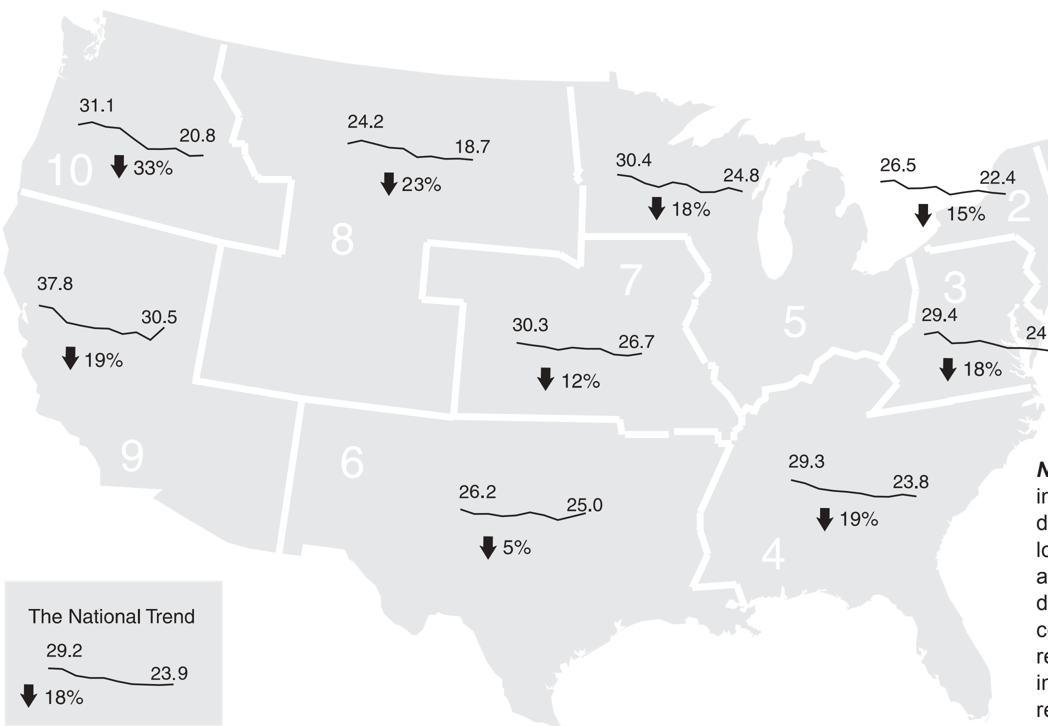


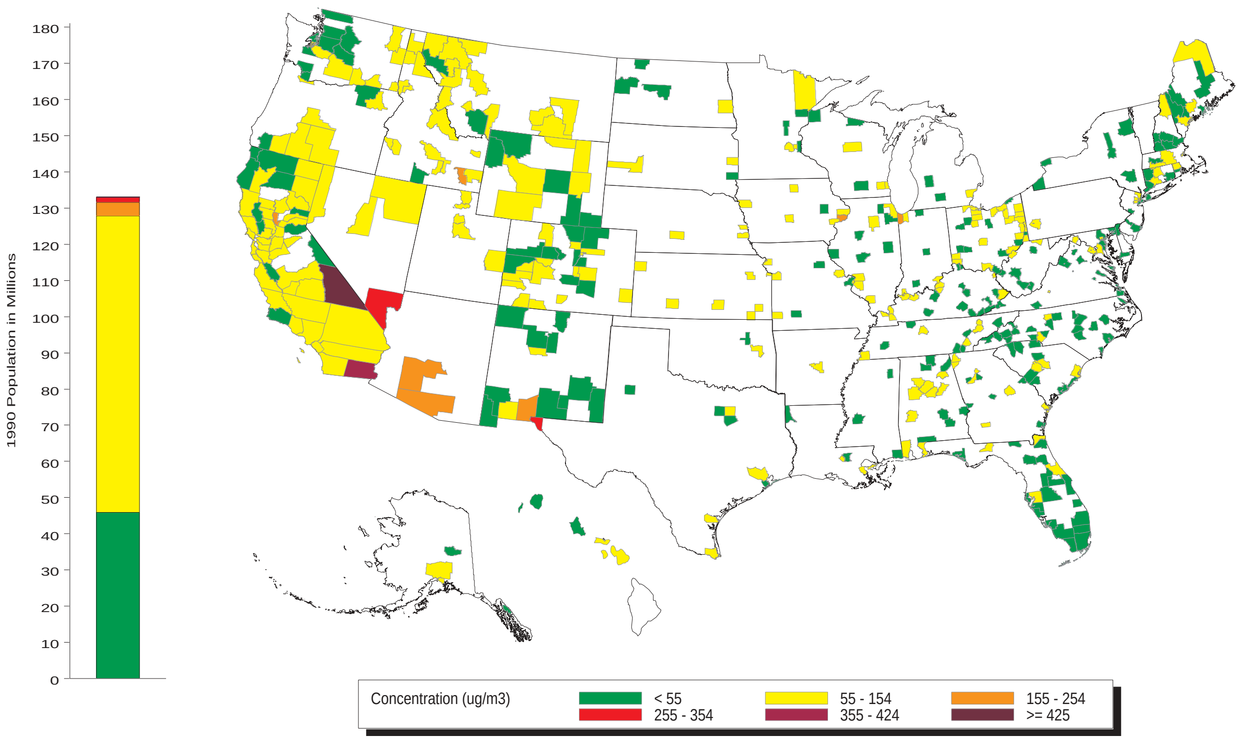
Figure 2-43. Trend in PM_{10} annual mean concentration by EPA region, 1990–1999.



Note: These trends are influenced by the distribution of monitoring locations in a given region and, therefore, can be driven largely by urban concentrations. For this reason, they are not indicative of background regional concentrations.

Alaska is in EPA Region 10; Hawaii, EPA Region 9; and Puerto Rico, EPA Region 2. Concentrations are µg/m3.

Figure 2-44. Highest 2nd maximum 24-hour PM_{10} concentration by county, 1999.



SO_2 and NO_x emissions, both precursors of particulate matter in the atmosphere (see Chapter 7 on Atmospheric Deposition and the SO_2 section in this chapter for more information on the Acid Rain Program).

PM_{10} 1999 Air Quality Status

The map in Figure 2-44 displays the highest second maximum 24-hour PM_{10} concentration in each county for 1999. The largest of these was recorded in Inyo County, California, caused by wind blown dust from a dry lake bed.[31] The bar chart which accompanies the national map shows the number of people living in counties within each concentration range. The colors on the map and bar chart correspond to the colors of the concentration ranges displayed in the map legend. In 1999, approximately 5 million people lived in 11 counties where the highest second maximum 24-hour PM_{10} concentration was above the level of the 24-hour PM_{10} NAAQS. When both the annual and 24-hour PM_{10} standards are considered, there were 20 million people living in 19 counties with PM_{10} concentrations above the NAAQS in 1999. See Chapter 4 for information concerning officially designated PM_{10} nonattainment areas.

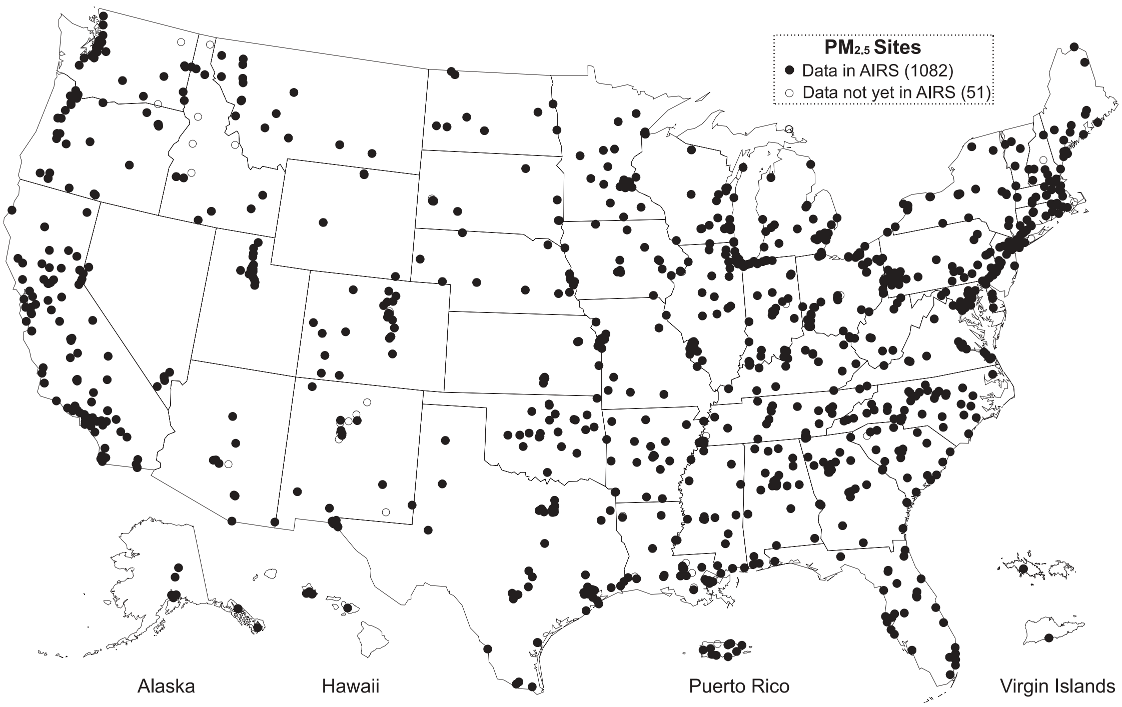
The Franklin Smelter facility, responsible for historically high recorded PM_{10} concentrations in Philadelphia, shut down in August 1997 and dismantled in late 1999.[32] This has brought peak concentrations down below the level of the standard at the nearby monitoring site. In 1998 and 1999, the second maximum was only 61 and 52 µg/m³, respectively, compared to 264 µg/m³ in 1997.

Characterizing $PM_{2.5}$ Air Quality

A new monitoring network designed to assess fine PM data with respect to the new $PM_{2.5}$ standards began deployment in early 1999. The status of this network is shown in Figure 2-45. As of February 2001, 1,108 Federal Reference Method (FRM) monitoring sites were operating and 1,044 of them have reported data to EPA's Aerometric Information Retrieval System (AIRS). Analyses of the first complete year of data (1999) collected by this network are summarized in the "FRM Network Results" section.

Data from another network, the IMPROVE network of rural sites, were used to assess the *composition* of and *trends* in ambient $PM_{2.5}$ concen-

Figure 2-45. Status of $PM_{2.5}$ monitor network, as of May 2001.



trations. Since the monitors in the IMPROVE network are non-FRM, the data cannot be used for compliance purposes. Analyses of these data are summarized in the "IMPROVE Network Results" section.

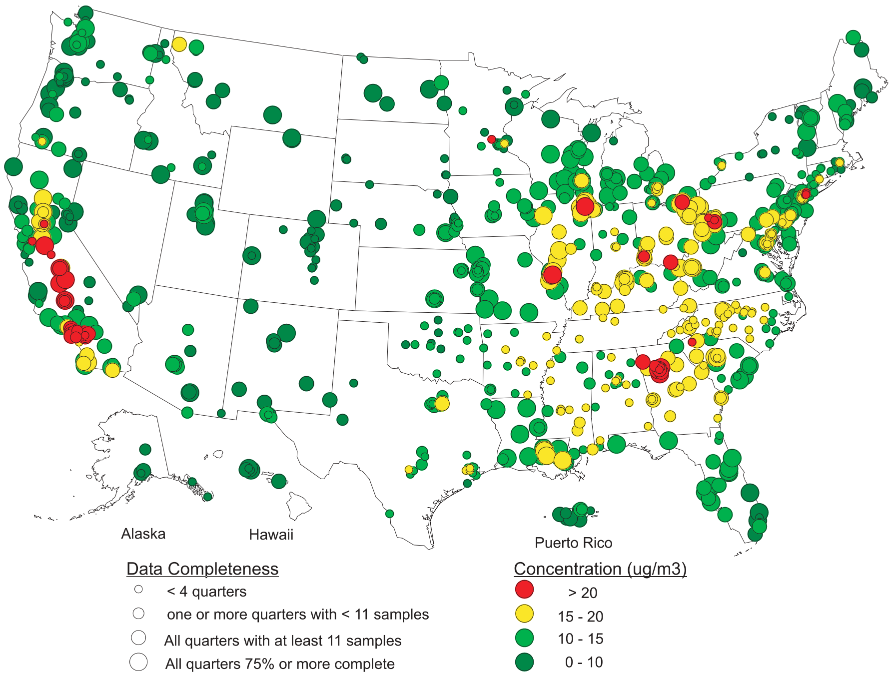
As additional analyses of $PM_{2.5}$ data are completed, they will be published on EPA's $PM_{2.5}$ Data Analysis Web site at **http://www.epa.gov/oar/oaqps/pm25/.**

FRM Network Results

1999 Annual Mean $PM_{2.5}$ Concentrations

Figure 2-46 depicts nationwide annual mean $PM_{2.5}$ concentrations from the FRM monitoring network. Data completeness is illustrated by the size of the circles on the map, with smaller circles indicating relatively incomplete data for the year. Many locations in the eastern United States and in California were above 15 µg/m³. Annual mean concentrations were above 20 µg/m³ in several major urban areas throughout the eastern United States including Pittsburgh, Cleveland, Atlanta, Chicago, and St. Louis. Los Angeles and the central valley of California also had levels above 20 µg/m³. Sites in the central and western mountain regions of the United States had generally low annual mean concentrations, most below 10 µg/m³.

Figure 2-46. 1999 annual mean $PM_{2.5}$ concentrations (µg/m³).



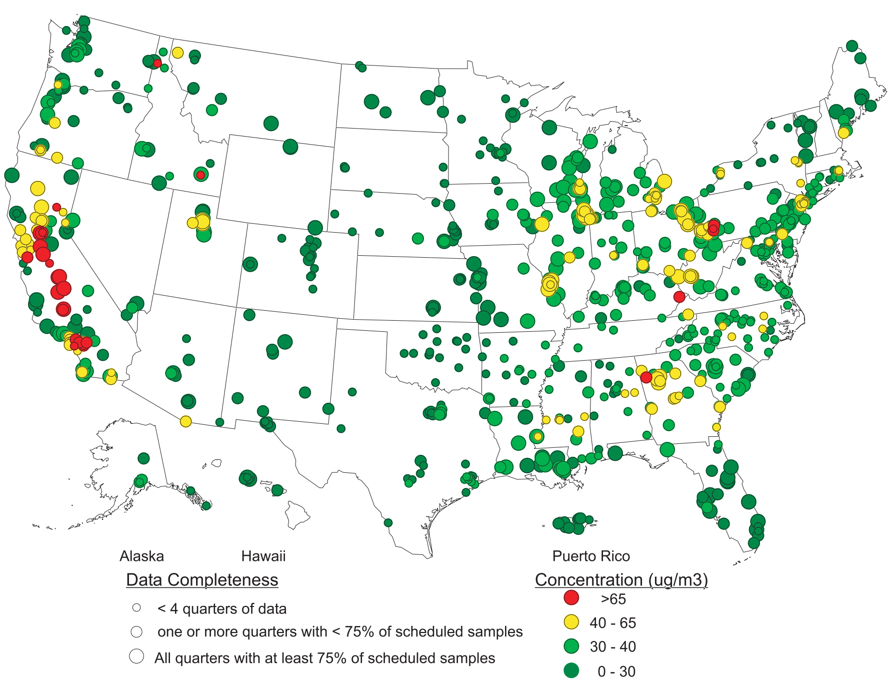
Source: US EPA AIRS Data base as of 7/12/00 without data flagged as 1, 2, 3, 4, T, W, Y, or X

1999 24-hour $PM_{2.5}$ Concentrations

Figure 2-47 depicts nationwide 98th percentile 24-hour average $PM_{2.5}$ concentrations from the FRM monitoring network. Concentrations above 65 µg/m³ are relatively rare in the eastern United States, but more prevalent in California. Values in the 40–65 µg/m³ range are more common in the eastern United States and the west coast, but relatively rare in the central and western mountain regions.

Readers should be cautioned not to draw conclusions regarding the attainment or nonattainment status inferred by a single year of $PM_{2.5}$ monitoring data. EPA regulations in *40 CFR* part 50, Appendix N, require three years of monitoring data and specify certain minimum data completeness requirements for data used to make decisions regarding attainment

Figure 2-47. 1999 98th percentile 24-hour average $PM_{2.5}$ concentrations (µg/m³).



Source: US EPA AIRS Data base as of 7/12/00 without data flagged as 1, 2, 3, 4, T, W, Y, or X

Figure 2-48. Urban $PM_{2.5}$ monthly patterns by region, 1999.

Notes: St. Louis and Buffalo = Industrial Midwest; Dallas = Southeast; Rochester = Northeast; Fresno, San Joaquin Valley, and Las Vegas = Southern California.

Hawaii, Alaska, and Puerto Rico are not included in regional summaries.

status. As indicated by the size of the circles on the maps, many sites have relatively incomplete data for 1999 at the time of the data summarization.

Seasonal Patterns in PM Concentrations

Data from the 1999 $PM_{2.5}$ FRM network show distinct seasonal variation in average $PM_{2.5}$ concentrations. The regional summaries in Figure 2-48 (urban) and Figure 2-49 (rural) demonstrate the geographic variability of $PM_{2.5}$ concentrations. The months with peak urban $PM_{2.5}$ concentrations vary by region. The urban areas in the eastern regions all show peaks in the summer months, and the western regions all show peaks in the winter months. The Industrial Midwest shows peaks in June and July, the upper Midwest shows peaks in July and August, and the Southeast shows peaks in August. The Northwest, Southwest, and Southern California all show peaks in January. The

Figure 2-49. Rural $PM_{2.5}$ monthly patterns by region, 1999.

Notes: St. Louis and Buffalo = Industrial Midwest; Dallas = Southeast; Rochester = Northeast; Fresno, San Joaquin Valley, and Las Vegas = Southern California.

Hawaii, Alaska, and Puerto Rico are not included in regional summaries.

Southwest and Southern California show a second peak in November.

Differences between urban and rural locations are apparent from the plots. Southern California urban and rural monitors show different seasonal patterns, with urban winter peaks not present in rural areas. In the Northwest the rural winter peak is not as pronounced as it is in urban areas. In all other regions the urban and rural patterns are very similar.

IMPROVE Network Results

The IMPROVE network was established in 1987 to track visibility impairment in the nation's most pristine areas, like national parks and wilderness areas. For this reason, the data primarily represent rural areas. There are, however, two non-rural sites (in Washington, D.C. and South Lake Tahoe) that use the same monitoring protocol. Data from these and other sites meeting data completeness criteria described in Appendix B, are presented in this section. Figure 2-50 shows the location of these sites by region. (The IMPROVE network is discussed in further detail in Chapter

Figure 2-50. Class I Areas in the IMPROVE Network meeting the data completeness criteria in Appendix B.

6: Visibility Trends. Also, visit **http://vista.cira.colostate.edu/improve/Data/IMPROVE/improve_data.htm** for more information concerning the IMPROVE network.)

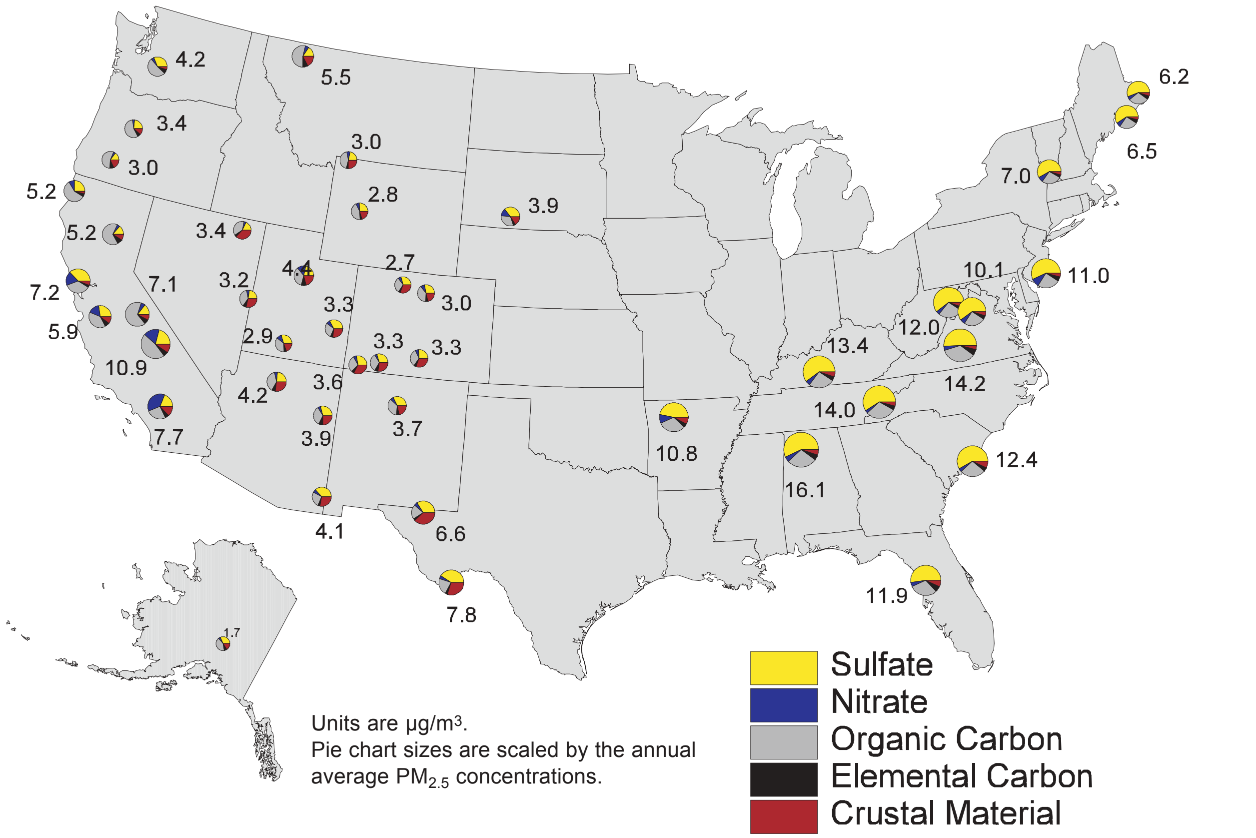
1999 Rural $PM_{2.5}$ Concentrations and Composition

Rural $PM_{2.5}$ concentrations vary regionally, with sites in the East typically having higher annual mean concentrations. Figure 2-51 shows the annual mean $PM_{2.5}$ concentrations in 1999. Much of the East/West difference is attributable to higher sulfate concentrations in the eastern United States. Sulfate concentrations in the eastern sites are 4–5 times greater than those in the western sites. Sulfate concentrations in the East largely result from sulfur dioxide emissions from coal-fired power plants. EPA's Acid Rain Program, which is discussed in more detail in the SO_2 section and in the SO_2 section in Chapter 7, sets restrictions on these power plants.

Within the East, rural $PM_{2.5}$ levels are higher in the Southeastern and mid-Atlantic states (ranging roughly from 10–16 µg/m^3), while the sites in the northeast are between 6–7 µg/m^3. In the West, rural $PM_{2.5}$ levels are generally less than 5 µg/m^3. California, Montana and Texas are the only states in the West with sites above that level.

The chemical composition of $PM_{2.5}$ also varies regionally. Sulfate and organic carbon account for most of the $PM_{2.5}$ concentrations in the East and the West. Sites in the East on average have a higher percentage of sulfate concentrations (56 percent) relative to those in the West (33 per-

Figure 2-51. Annual mean $PM_{2.5}$ concentrations in 1999.

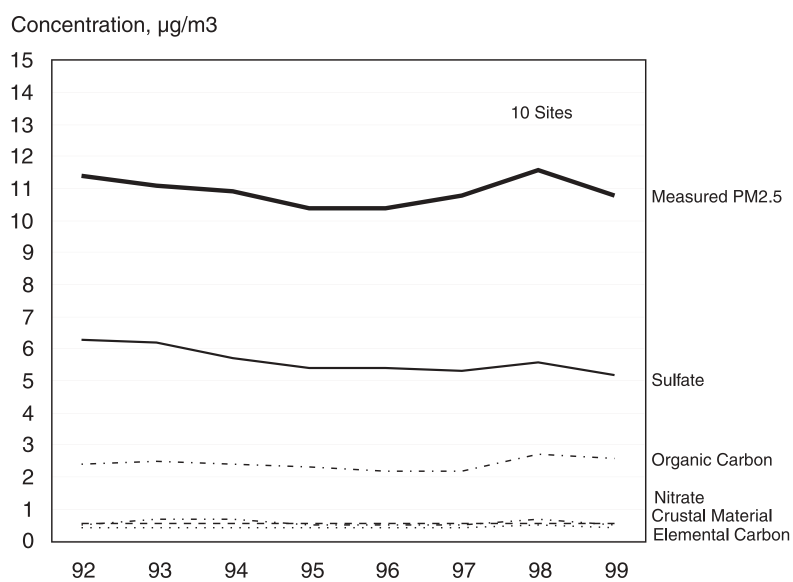


cent). Table 2-5 shows the difference in percent contribution of each species for the eastern versus western regions of the United States.

Table 2-5. Percent Contribution to $PM_{2.5}$ by Component, 1999

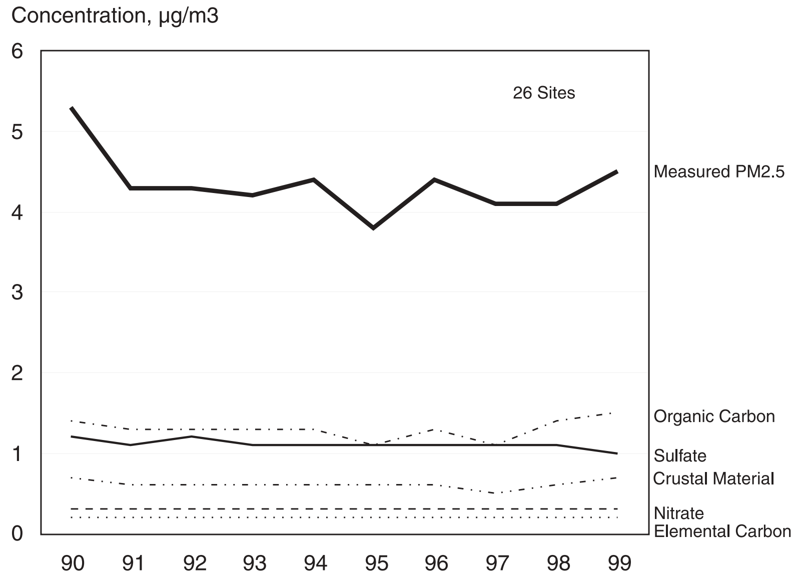
	East (10 sites)	West (26 sites)
Sulfate	56	33
Elemental Carbon	5	6
Organic Carbon	27	36
Nitrate	5	8
Crustal Material	7	17

Figure 2-52. $PM_{2.5}$ concentrations, 1992–1999 at eastern IMPROVE sites meeting trends criteria.



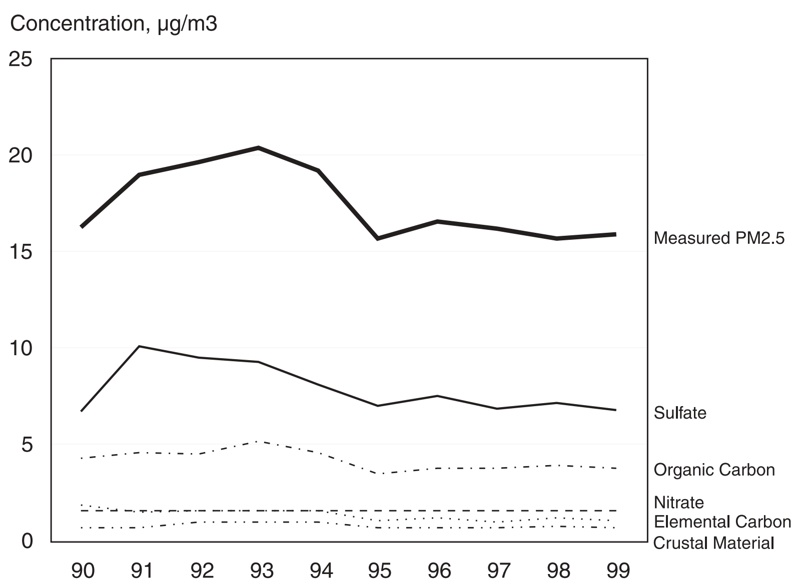
Note: Measured PM2.5 represents the direct mass measurement from the filter. The sum of the component concentrations do not equal this value because they do not account for all measured mass.

Figure 2-53. $PM_{2.5}$ concentrations, 1990–1999 at western IMPROVE sites meeting trends criteria.



Note: Measured PM2.5 represents the direct mass measurement from the filter. The sum of the component concentrations do not equal this value because they do not account for all measured mass.

Figure 2-54. $PM_{2.5}$ concentrations, 1990–1999 at the Washington D.C. IMPROVE site.



Note: Measured PM2.5 represents the direct mass measurement from the filter. The sum of the component concentrations do not equal this value because they do not account for all measured mass.

$PM_{2.5}$ Air Quality Trends in Rural Areas

Because of the significant regional variations in rural $PM_{2.5}$ concentrations, trends are aggregated by eastern and western regions as shown in Figures 2-52 and 2-53. Based on the 10 sites with trend data in the East, average $PM_{2.5}$ concentrations in the rural east decreased 7 percent from 1998–1999. The 1999 level is down 5 percent from the 1992 level, but it is up 4 percent from the 1995 level (the lowest level during the trend period). Sulfate concentrations in the rural east decreased 7 percent from 1998 to 1999. Organic carbon concentrations in the rural east decreased 4 percent from 1998–1999, but are still up 18 percent from 1997 (the lowest level during the trend period).

The average $PM_{2.5}$ concentrations in the West increased 10 percent from 1998–1999. However, the 1999 level is down 15 percent from the 1990 level.

$PM_{2.5}$ Trends in Non-rural Areas

Figure 2-54 shows that annual average $PM_{2.5}$ concentrations at the Washington, D.C. site decreased 2 percent between 1990 and 1999, but increased 1 percent between 1998 and 1999.

Characterizing $PM_{2.5}$ Emissions

To get some idea of the nature of fine PM, some emissions information coupled with ambient data measurements can be examined. EPA is working to improve the $PM_{2.5}$ emission inventory. In the meantime, a general assessment of the emission sources contributing to $PM_{2.5}$ can be obtained by evaluating $PM_{2.5}$ monitoring data in conjunction with emission inventory information. The paragraphs below provide a broad overview of the nationwide concentrations, composition, and sources of

$PM_{2.5}$ based on actual $PM_{2.5}$ measurements and the emission inventory of sources contributing within each composition category.

$PM_{2.5}$ is composed of a mixture of particles directly emitted into the air and particles formed in the air from the chemical transformation of gaseous pollutants. The principal types of secondary particles are ammonium sulfate and ammonium nitrate formed in the air from gaseous emissions of SO_2 and NO_x, reacting with ammonia. The main source of SO_2 is combustion of fossil fuels in boilers and the main sources of NO_x are combustion of fossil fuel in boilers and mobile sources. Some secondary particles are also formed from volatile organic compounds which are emitted from a wide range of combustion and other sources.

The principle types of directly emitted particles are those that predominantly consist of crustal materials and those consisting of elemental and organic carbonaceous materials resulting from the incomplete combustion of fossil fuels and biomass materials. The main sources of crustal particles are road surface materials, construction activity, and certain agricultural activities. The main sources of combustion-related particles are mobile sources such as diesels, managed and unmanaged biomass burning, residential wood combustion, utility, commercial and industrial boilers. Note however, that crustal particles contain some carbonaceous materials, some combustion process emissions contain crustal materials (e.g., wild and prescribed fires), and even fossil fuels contain fly ash that is chemically similar to soil and thus would be classified as crustal in the compositional analysis of ambient samples reported herein.

Figure 2-55 summarizes information from actual measurements of ambient $PM_{2.5}$. It shows how $PM_{2.5}$ composition varies in both the eastern and western United States. The ambient samples were chemically analyzed to determine the amount of ammonium sulfate and nitrate, crustal material and carbonaceous material. The concentration and composition data are based on at least one year of data from each monitoring location, with the exception of Denver. The data were collected using a variety of non-federal reference methods and should not be used to determine compliance with the $PM_{2.5}$ NAAQS. The composition information represents a range of urban and non urban locations. The published composition data for the East are somewhat limited, but preliminary information from several recently completed urban studies is included. It shows relatively consistent composition of $PM_{2.5}$ across much of the East. The available information consistently shows that $PM_{2.5}$ in the East is dominated by ammonium sulfate on a regional scale and also by carbonaceous particles emitted directly by combustion processes. Regional concentrations of $PM_{2.5}$ are generally higher throughout much of the East, due to the regional influence of ammonium sulfate caused by higher SO_2 emissions throughout much of the East and the ubiquitous nature of combustion processes. (See Chapter 7 for a description of spatial patterns and trends of sulfate air quality.) The regional concentrations of $PM_{2.5}$ are lower in the western United States than in the East and the composition is more variable. The west differs from the East in two important ways. First, non urban $PM_{2.5}$ concentrations are much lower in the West than in the East. This is because the East is blanketed regionally by relatively higher concentrations of ammonium sulfate, whereas regional sulfate concentrations in the West are much lower. Second, several western areas, notably the San Joaquin Valley and the Rubidoux area California's South Coast basin have higher ammonium nitrate concentrations. Nitrate concentrations are also higher in non-urban inland areas of southern California. Such pockets of high nitrate concentrations are not as pronounced in the East. Crustal material is a relatively small constituent of $PM_{2.5}$ in both the West and east, even in arid and agricultural areas such as Phoenix, Arizona and the San Joaquin Valley of California.

Figure 2-56 depicts the link between sources and the composition components of $PM_{2.5}$. EPA has developed a National Emissions Inventory (NEI) inventory for use in analyzing trends in emissions over time, conducting various in house analyses for PM, and for use in regional scale modeling.[33] The NEI covers all 50 states and includes point, area, onroad mobile, nonroad mobile sources and biogenic/geogenic emissions. Point sources are identified individually while county tallies are used for area and mobile source category groups. The inventory includes emissions of SO_2, NO_x, VOC, CO, PM_{10}, $PM_{2.5}$, and NH_3. Of these pollutants, only carbon monoxide is not a contributor to the ambient fine particle burden.

Figure 2-56 provides a link between the sources in the NET inventory and the composition information shown in Figure 2-55. The stacked bar graphs show the relative magnitude of emissions of sulfur dioxide,